MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EME3206 – CONTROL ENGINEERING

(ME)

6 MARCH 2019
9:00 a.m. –11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages excluding cover page with 4 Questions only.
2. Attempt **ALL FOUR COMPULSORY** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.
4. Table of Laplace Transform pairs has been included in Appendix.

Question 1

(a) Consider a rotational mechanical system as shown in Figure Q1a.

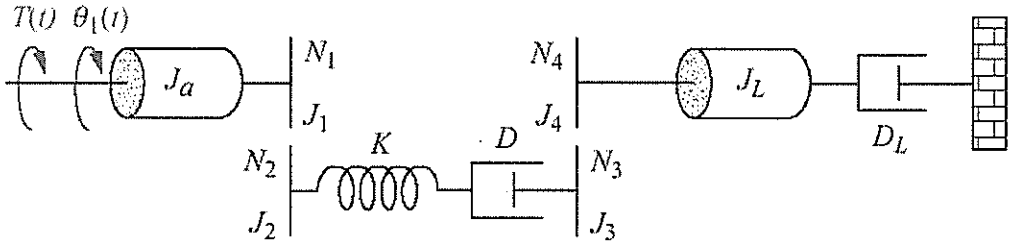

Figure Q1a

(i) Find the equivalent moment of inertia, J_e, coefficient of viscous friction, D_e, and spring constant, K_e, by reflecting the impedances to the input shaft.

[6 marks]

(ii) Draw the equivalent diagram consists of $T(s)$, $\theta_1(s)$, J_e, D_e, and K_e.

[2 marks]

(iii) Given the numerical values of moment of inertia, coefficient of viscous friction, spring constant and gear ratio in Table Q1a(iii).

Moment of inertia ($kg\text{-}m^2$)	Coefficient of viscous friction ($N\text{-}m\text{-}s/rad$)	Spring constant ($N\text{-}m/rad$)	Gear ratio
$J_L = J_1 = J_3 = 2$ $J_a = J_2 = J_4 = 1$	$D_L = 3$ $D = 5$	$K = 4$	$N_1 = 50$ $N_2 = N_4 = 100$ $N_3 = 25$

Table Q1a(iii)

Determine the transfer function $\frac{\theta_1(s)}{T(s)}$. [5 marks]

(b) Consider a mechanical system as shown in Figure Q1b.

(i) Convert the block diagram into a signal-flow graph. Simplification of the signal-flow graph is optional.

[6 marks]

(ii) Using Mason's Rule, find the transfer function $\frac{C(s)}{R(s)}$ for the signal-flow graph drawn in question b(i).

[6 marks]

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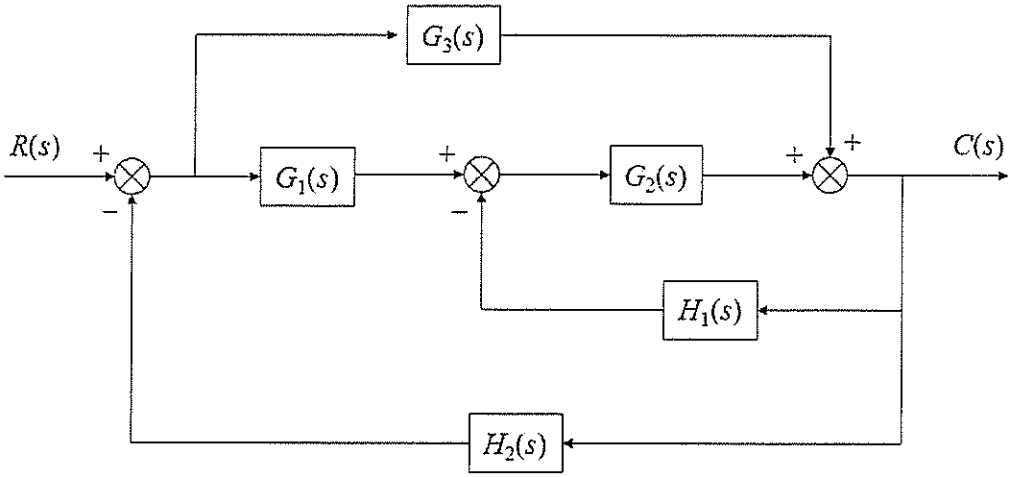

Figure Q1b

Question 2

(a) Consider the open-loop transfer function of a unity feedback system, $G(s) = \frac{1}{s(s+1)}$ which is fed with unit step input. Determine

(i) Natural frequency (ω_n) [2 marks]
(ii) Damping ratio (ξ) [2 marks]
(iii) Rise time (t_r) [2 marks]
(vi) Peak time (t_p) [2 marks]
(v) Maximum overshoot (M_p) [2 marks]

(b) For the system shown in Figure 2b, find the value of K and K_t so that the system will have a damping ratio of 0.6 and a settling time of a unit step input response of 0.1s.

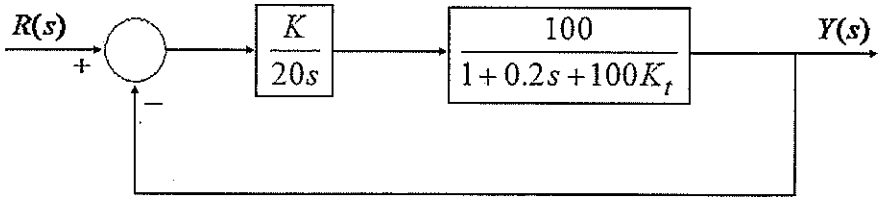

Figure Q2b

[15 marks]

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Question 3

(a) Figure Q3a shows a negative unity feedback system with input $X(s)$ and output $Y(s)$.

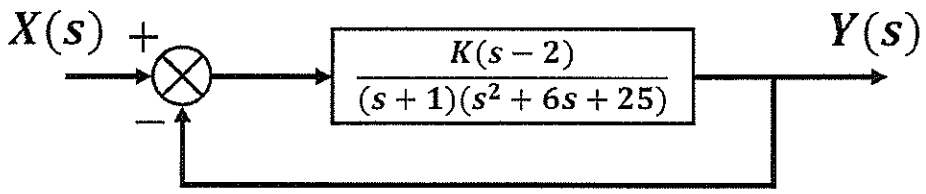

Figure Q3a

(i) Determine the characteristic equation of the system. [3 marks]

(ii) Construct the Routh's table. [5 marks]

(iii) Determine the range of K for stability using ***Routh-Hurwitz Criterion***. [2 marks]

(b) Consider the following open loop transfer function, $G(s)H(s)$ of a control system.

$$G(s)H(s) = \frac{K(s+7)(s+3)}{s(s-4)}$$

(i) Determine the number of root loci branches. [1 mark]

(ii) Determine the root loci on the real axis. [1 mark]

(iii) Find the intersection of root loci with the imaginary axis. [5 marks]

(iv) Find the Break-away/Break-in point. [4 marks]

(v) Construct and label the root loci of the system. [4 marks]

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Question 4

(a) Sketch the asymptotic magnitude Bode plot for the following open loop transfer function:

$$G(s)H(s) = \frac{1}{s(s+1)(s+10)}$$

[12 marks]

(b) Figure Q4b shows a one-mass system with the applied force, $f(t)$; displacement, $y(t)$; mass, M; spring constant, K; and rolling friction constant, B.

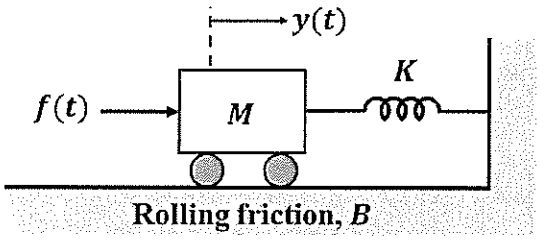

Figure Q4b

(i) With the aid of a free body diagram, determine the differential equation that represents the system. [3 marks]

(ii) Based on the answer in part (b)(i), construct the state diagram. [5 marks]

(iii) Formulate the state space model that represents the system. [5 marks]

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Appendix – Laplace Transform Pairs

f(t)	F(s)
Unit impulse δ (t)	1
Unit step u(t)	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!}$ (n = 1, 2, 3, …)	$\frac{1}{s^n}$
t^n (n = 1, 2, 3, …)	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at} \cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$1-\cos \omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t - \sin \omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin \omega t - \omega t \cos \omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega} t \sin \omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t \cos \omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$

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